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Ten men were dehydrated by voluntary restriction of fluid intake and by mild exercise over a 2-1/2 day period (body weight loss: 4.6%). Body weight returned to -1.6% and -0.3% of their starting weight 10 to 20 hours after rehydration, respectively, suggesting the weight loss was fluid loss. Measures of blood and urine constituents also were indicative of dehydration.

These 10 experimental subjects experienced a standard cold test prior to and after dehydration and after rehydration. The standard cold test consisted

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of sitting in a cold chamber (0°) dressed in cold weather clothing with right hand bare for 2 hours. The fingers, but not the back of the hand, of the experimentals were significantly colder ($P > .05$) following dehydration and were slightly warmer following initial rehydration. A group of 10 control subjects tested under identical conditions, but hydrated at all times, showed no changes.

(0°C)

THE EFFECTS OF DEHYDRATION ON PERIPHERAL COOLING

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Running Title: The Effects of Dehydration on Peripheral Cooling

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ABSTRACT

Ten men were dehydrated by voluntary restriction of fluid intake and by mild exercise over a 2-1/2 day period (body weight loss: 4.6%). Body weight returned to -1.6% and -0.3% of their starting weight 10 to 20 hours after rehydration, respectively, suggesting the weight loss was fluid loss. Measures of blood and urine constituents also were indicative of dehydration.

These 10 experimental subjects experienced a standard cold test prior to and after dehydration and after rehydration. The standard cold test consisted of sitting in a cold chamber ($0^{o}C$) dressed in cold weather clothing with right hand bare for 2 hours. The fingers, but not the back of the hand, of the experimentals were significantly colder ($P > .05$) following dehydration and were slightly warmer following initial rehydration. A group of 10 control subjects tested under identical conditions, but hydrated at all times, showed no changes.

INTRODUCTION

Differences in physiological response to peripheral cooling have been reported as a result of environmental factors, such as prior cold exposure (acclimation) (2,12,13) and physical training (1,8). Possible genetic and racial differences have also been noted (4,7,10,14).

One environmental factor which may be important in altering peripheral response to cold is the state of hydration of individuals. Loss of fluid in the cold may be predicted on the basis of (a) decreased availability of water (snow or ice must be melted), (b) increased exercise-induced sweat loss in heavy clothing, (c) loss of appropriate thirst response, and (d) cold induced diuresis.

However, the state of hydration of civilian and military persons living and working in cold climates is relatively unknown. Limited data support the hypothesis that dehydration may be a common phenomenon in cold climates. For example, men exposed to arctic survival conditions in tents with ad libitum water (no food) lost 8% of their body weight in 5 days. Based on electrolyte loss, a 5% decline of their body weight was attributed to fluid loss (15). In a Canadian military exercise, lasting 5 days, a fluid loss of 3% was estimated (16). Recent US military exercises in Alaska produced a casualty rate of 1.8% that was attributed to dehydration by the examining physician (17).

Such dehydration may alter the peripheral response to cooling. It is known that peripheral heat transfer rates in a warm environment are affected by the state of hydration, even in a resting subject (9). This study showed that dehydration caused an increase in heating rate, in part due to a reduction in peripheral blood flow. A similar response in a cold environment should cause an increase in cooling rate. Since there have been no studies of the effect of dehydration on peripheral response to cold, the present study was undertaken.

METHODS

To determine the effects of dehydration on cooling of the hands, 12 male subjects (experimentals) were exposed to a standard hand cooling test at 3 different periods: prior to and after dehydration and after rehydration. A similar group of 12 subjects (controls) was tested under identical conditions except they were allowed to drink fluid.

Logistics. Subjects (either an experimental or a control group) (Table 1) reported to the test site on Sunday evening prior to 1900. The subjects were fed that evening and then retired for the night prior to 2300. The subjects remained at the test site from Sunday evening until the following Friday afternoon. They were awakened at 0630 each day and retired no later than 2300. They were fed 4 times a day: at 0700, 1130, 1730, and 2130. Meals consisted of frozen TV dinners and other packaged frozen foods. The menu was different for each day of the week, but the same weekly menu was eaten by all groups. Although exact caloric balance was not calculated, food intake exceeded 2500 kcal per day. When not scheduled for cold tests, subjects were free to engage in activities of their choosing. (An overview of the weekly schedule is presented as Figure 1.).

All subjects experienced the standard hand cooling test at least one week prior to their test week to minimize novelty effects. During the test week, all subjects experienced the standard cold test on 3 different days: Monday (both controls and experimentals hydrated); Thursday (experimentals dehydrated); and Friday (experimentals rehydrated). Subjects experienced the cold test either in the morning or afternoon. These data were pooled since each subject was run at the same time each day of the week and minimal diet effects would be expected from 0900 to 1300 (5).

Dehydration. The primary measure of dehydration was body weight loss. Each subject was weighed each morning immediately upon arising to obtain a

systematic weight. Weights were taken clad only in shorts to the nearest 0.01 kg using a calibrated balance.

As indirect corroborators of dehydration, measures of various blood and urine constituents were made. A blood sample was drawn each morning in the supine position before arising by venipuncture of the antecubital vein. Urine samples were collected as 12 hour samples starting Monday at 0630 and continuing for the entire week. Blood samples were analyzed for hematocrit, hemoglobin, serum osmolality, sodium, potassium and chloride by standard clinical methods. Volumes of the 12 hour urine samples were measured and the urine analyzed for specific gravity, osmolality, sodium, potassium and chloride.

Starting at 1400 Monday, the experimental subjects were dehydrated by voluntary restriction of fluid intake and by mild exercise. Apart from the fluid contained in their meals, the experimental subjects received only one liter of fluid over the course of the dehydration period which lasted until Thursday evening (1/3 L each night at 2130). The mild exercise consisted of intervals of running (6 mph - 0 grade) on a treadmill or riding a stationary bicycle (50 watts) for a total of 1-2 hours each day. Subjects rehydrated freely Thursday starting at 2000.

Cold Test. The standard cold test consisted of sitting in a cold chamber ($0^{\circ}C$) dressed comfortably in standard military cold weather clothing for 135 minutes. After 15 minutes, the mitten, mitten liner and glove liner were removed from the right hand and the bare hand rested on plastic mesh material to allow air circulation. Wind speed at the subjects' exposed hand was less than 0.5 m sec^{-1}.

The temperature of the right hand was measured at 4 sites: thumb, middle finger, little finger and back of hand. Finger temperatures were measured just proximal to the nail bed with exposed copper-constantan thermocouples fastened

in place with plastic tape. Skin temperatures were measured at the same 4 sites on the left (gloved and mittened) hand and at 8 additional sites: forehead, right upper arm, left forearm, chest, abdomen, lower back, right medial thigh and right lateral calf. Weighted mean skin temperatures (MWST) were calculated by the equation of Wenger et al. (19). Rectal temperature (T_r) was also measured by thermocouple. Subjects were removed from the cold chamber whenever any skin temperature reached 4.5°C (safety temperature to preclude cold injury).

All thermocouple voltages were acquired, linearized and referenced to an electronic zero degrees by Numatron scanning system (Leeds and Northrup). The Numatron system was linear when checked with regulated water baths and any temperature value was accurate to ±0.3°C over the range of temperatures used in the study.

The normal BCD output of the temperature value from the Numatron was modified to a serial pulse voltage output using a Serdex 2603 transmitter card (Analog Devices). These voltage pulses were recorded on magnetic tapes which were played back at a later date for acquisition by a PDP-11/.0 minicomputer. For final data calculation, each thermocouple value for all subjects was acquired by the minicomputer once per minute.

It was felt that any individual temperature value at any time provides little information about the thermal state of the subjects' hands. For, at any given time, various states in a local cold-induced vasodilation (CIVD) might be sampled. The pattern of CIVDs also is a less than satisfactory measure. Therefore, the area under the temperature-time curve was calculated using a simple algorithm to integrate the temperature values across time (Figure 2). This area expresses the average thermal state of the hand over the entire time period and has been found to be the most reproducible of any index of hand thermal response to cold (11).

Subjects were removed from the cold chamber when any skin temperature reached 4.5°C. This occurred in 8 runs out of a possible 60 runs. In order to compare these data to completed runs, an adjusted area was calculated by assuming that any temperature measured at the time of removal would have remained at that value for the remainder of the cold test.

This technique permitted comparison for all subjects studied; otherwise, with varying times of removal, comparison would be complicated. The area would be less if calculated only to the time of removal so the adjusted area method would tend to artificially inflate and therefore bias the data. This technique is preferable to comparing only the actually measured area (11), which would tend to show an artificially low area when compared to a completed run. The present technique also is preferable to omitting subjects removed prior to 135 minutes, since the data would then be biased for cold-tolerant individuals. It should be noted that the experimental subjects were removed from the chamber more frequently and at earlier times on Thursday. It should also be noted that comparison of data for only those subjects who lasted 135 minutes for all standard cold tests would not alter the interpretation of results, but would reduce the number of observations.

In addition to the temperature values, expired gas samples were collected periodically in Douglas bags during the standard cold tests. These samples were analyzed for volume, oxygen and carbon dioxide content using a 150L Tissot spirometer, an Applied Electrochemical fuel cell and a Statham Capnograph, respectively. These values were used to calculate oxygen consumption.

Data Analysis. Data were analyzed by a general analysis of variance program which included a repeated measures model. Whenever an F value was significant ($P < .05$), critical differences between individual mean values were calculated using Scheffe's test. Individual mean differences were accepted as significantly different whenever $P > .05$.

RESULTS

Dehydration. Indirect measures were utilized as indicators of dehydration; loss of body weight was the primary indicator. The experimental group lost 4.6% of their body weight over a 2-1/2 day period. Within 10 hours of the initiation of fluid replacement, the experimental group recovered to a weight deficit of 1.9% (Friday morning). Over the same time course, the controls' weight did not change. The experimentals' Friday afternoon weight was only 0.3% lower than their beginning weight (20 hours after rehydration).

Most blood values showed no consistent alteration between the experimental versus control group or across time (Table 2). However, serum osmolality increased significantly from baseline values for the experimental group on Thursday ($P < .05$) and were significantly different from control group values ($P < .01$).

Significant decrease in urine volume of the experimental group occurred following restriction of fluid intake Monday afternoon (Table 3). Urine volumes for the experimental group were significantly lower than the Monday 0630-1830 base line volume ($P < .001$) and also significantly lower than the corresponding control group volume (lowest $P < .05$). Baseline volumes of the two groups were not different.

Changes in specific gravity essentially parallelled the changes in urine volume. Specific gravities were not significantly different between groups for either Monday collection period. Subsequently, values were different for all periods ($P < .001$). The experimental group specific gravity values for the first three and last (Friday) collection period were not significantly different; the remaining values were different from these four periods ($P < .05$).

Urine sodium and chloride values were not different between groups. In contrast, urine potassium values were significantly higher for the experimental

group for all collection periods except the first and last ($P < .01$). Across time, only the Thursday experimental value was significantly different from the other values ($P < .05$).

Urine osmolality values for the experimental versus control groups did not differ significantly for the Monday baseline and Wednesday morning collections. The remaining values all differed (lowest $P < .05$).

Whole Body Cooling. To determine whether the whole body thermal state of the subjects differed from day to day, the mean values for T_r and MWST were calculated for the 135 minute cold test (Table 4). There were no differences between groups or across the 3 periods of cold testing. The slight degree of cooling in all tests (T_r declined $0.5^{\circ}C$) was reflected by slight increases in oxygen consumption during the standard cold tests (Figure 3).

Peripheral Responses to Cooling. The areas under the temperature-time curve for the control subjects were the same for all periods of standard cold tests (Table 5). Preliminary cold test values were not available for 5 subjects due to equipment failure.

The preliminary and Monday standard cold test values for the experimental group were virtually identical. Subsequently, the area under the curve dropped on Thursday (following dehydration) and partially returned toward the Monday values on Friday. The area under the cooling curve for eight of the 10 experimental subjects was higher on Friday than Thursday, while lower Friday values for the other 2 subjects may have masked any reduced cooling following rehydration.

The values for the area under the curve are listed (Table 5) (a) to indicate the reproducibility of the test and (b) to indicate the relative magnitude of the values. Inspection of the data indicates that the baseline values of the control and experimental group are not homogeneous. This difference occurred despite

the fact that subjects were randomly assigned to control and experimental groups. It was not possible to conduct the preliminary cold tests, match subjects and then randomly assign to control/experimental group because all test subjects were not available at the start of the study. The lack of homogeneity is unfortunate, but not critical, since each subject was his own control for the Thursday and Friday standard cold tests.

To eliminate the differences in baseline values for the groups, the data were calculated as the difference for each subject from his baseline (Monday) value for Thursday and Friday (Figure 4).

There were no differences either across time or between groups, for the right back of hand area. In contrast, the area under the cooling curve was less for the experimental group on both Thursday and Friday than that for the control group ($P < .001$). For the experimental group, this decreased area on Thursday was significantly different from pre-dehydration values ($P < .001$). The area for the right thumb remained low on Friday (Rehydration) and was significantly different from Monday. In contrast, the area for the middle and little finger had increased sufficiently on Friday (Rehydration) so that it was not significantly different from either pre-dehydration or dehydration values. In all cases, the control group declines were not significantly different from each other or from zero (baseline).

DISCUSSION

The central question posed was: After dehydration, does the hand cooling of the experimental subjects change? Before examining data that may answer this question, three preliminary questions ought to be addressed: (a) What is the evidence that the experimental group did, in fact, dehydrate? (b) Could any differences which may have occurred result from differences in the whole body thermal state from day to day? (c) To what extent do hand cooling responses result from whole body cooling during the standard cold tests?

The rapid recovery of weight loss indicated that it was more likely due to loss of water, not body tissue. Hemoconcentration (increased serum osmolality) and urine concentration and decreased volume are the physiological changes one would expect to find in dehydrated subjects. Thus, the changes in blood and urine parameters, coupled with the maintenance of caloric intake strongly supports the development of dehydration by the experimental subjects.

Direct measures of fluid volumes (total body water, plasma volume, extracellular fluid volume) would have been desirable to confirm and localize the site of fluid loss, but these measurements were not done in this study. Plasma volume was calculated according to the predictive equation of Dill and Costill (6); however, the results were not conclusive. For the experimental subjects a change from baseline of +2.3 ($\pm$SE 1.8%) occurred. This change was not significantly different from zero, that is, no change of plasma volume. One might have predicted a decrease in calculated plasma volume and an increase in hematocrit for the experimental subjects, but this did not occur.

Large decreases in plasma volume have been found in a number of studies as a result of acute dehydration from heat exposure with and without exercise (6). These acute decreases probably do not reflect true changes of hypohydration. However, a decline of 4.4% for calculated plasma volume was found in a similar study (3). In that study, high school wrestlers exercised and restricted fluid intake for two days, but also starved themselves. Without actual measures of plasma volume, we find it difficult to conclude whether or not plasma volume changed in the experimental subjects.

The whole body cooling which occurred during the standard cold tests was slight, and, at any rate, the same for both groups and the same for all standard cold tests.

Nonetheless, the experimental subjects' hands were significantly colder following fluid loss. The area under the temperature-time curve (that is, average temperature) was 18% lower than their baseline value. The cooler finger temperatures almost certainly represent decreased finger blood flow, since finger blood flow is approximately 90% skin blood flow and there is little metabolizing tissue (18).

Decreased finger blood flow could result from decreased plasma volume. Even without decreased plasma volume, blood pooling in the core with reduced peripheral circulating blood volume still could occur. In part, the response could be attributed to a neurogenic reflex resultant from the fluid loss. Obviously this study did not address mechanisms of reduced peripheral blood flow. Rather, our question was simply to identify whether or not increased peripheral cooling occurred in the presence of dehydration.

The data presented indicates that dehydration can result in a colder hand and as such may lead to increased incidence of cold injury. It is recommended that persons exposed to field conditions where dehydration can occur be very careful to maintain hydration to avoid increased risk of cold injury.

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The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 in Use of Volunteers in Research.

REFERENCES

1. Adams, T. and E.J. Heberling. Human physiological responses to a standardized cold test as modified by physical fitness. J. Appl. Physiol. 13:226-230, 1958.

2. Adams, T. and R.E. Smith. Effect of chronic local cold exposure on finger temperature responses. J. Appl. Physiol. 17:317-322, 1962.

3. Allen, T.E., D.P. Smith and D.K. Miller. Hemodynamic response to submaximal exercise after dehydration and rehydration in high school wrestlers. Med. Sci. Sports 9:159-163, 1977.

4. Andersen, K.L. Comparison of Scandinavian Lapps, Arctic Fishermen and Candian Arctic Indians. Fed. Proc. 22:834-839, 1963.

5. Aschoff, J. and A. Heise. Thermal conductance in man: Its dependence on time of day and on ambient temperature. In: Advances in Climatic Physiology, ed. S. Itoh, K. Ogata and H. Yoshimura. Berlin: Springer-Verlag, pp. 334-348, 1972.

6. Dill, D.B., and D.L. Costill. Calculation of percentage changes in volume of blood, plasma and red cells in dehydration. J. Appl. Physiol. 37:247-248, 1974.

7. Elsner, R.W., J.D. Nelms and L. Irving. Circulation of heat to the hands of Arctic Indians. J. Appl. Physiol. 15:662-666, 1960.

8. Fusio, R.A. and B. Gutin. Effects of exercise training on cardiovascular response of human subjects to a localized cold stressor. Amer. Corr. Ther. J. 28:42- , 1974.

9. Horstman, D.H. and S.M. Horvath. Cardiovascular and temperature regulatory changes during progressive dehydration and euhydration. J. Appl. Physiol. 33:446-450, 1972.

10. Iampietro, P.F., R.F. Goldman, E.R. Buskirk and D.E. Bass. Response of Negro and white males to cold. J. Appl. Physiol. 14:798-800, 1959.

11. Jaeger, J.J., J.B. Sampson, D.E. Roberts, and J.E. McCarroll. Characteristics of human finger cooling in air at 0°C. Physiologist 20:47, 1977.

12. Leblanc, J., J.A. Hlides and O. Heroux. Tolerance of Gaspe fishermen to cold water. J. Appl. Physiol. 15:1031-1034, 1960.

13. Nelms, J.D. and D.J.G. Soper. 'Cold vasodilation and cold acclimatization in the hands of British fish filleters. J. Appl. Physiol. 17:444-448, 1962.

14. Rennie, D.W. and T. Adams. Comparative thermoregulatory responses of Negroes and white persons to acute cold stress. J. Appl. Physiol. 11:201-204, 1957.

15. Rogers, T.A., J.A. Setliff and J.C. Lopping. Energy cost, fluid and electrolyte balance in subarctic survival situations. J. Appl. Physiol. 19:1-8, 1964.

16. Sabiston, B.H. and S.D. Livingston. Investigation of health problems related to Canadian northern military operations. Defense and Civil Institute of Environmental Medicine Report No. 899. Downsview, Ontario, Canada, 18 p, 1973.

17. Smith, F.A., C.D. Bickley, A. Watson, J.C. Roots, R.S. Grischkowsky, D.W. Orr, J.L. Mead and F.G. Paul. Arctic and Cold Weather Warfare Staff Study and Recommendations: Supplemental Material to the "Arctic Mobility Study" of VTU 12-50. Anchorage, Alaska: USMCR 12-50, 96 p., 1977.

18. Wenger, C.B., M.F. Roberts, J.A.J. Stolwijk and E.R. Nadel. Forearm blood flow during body temperature transients produced by leg exercise. J. Appl. Physiol. 38:58-63, 1975.

FIGURE LEGENDS

Figure 1. Overview of the weekly schedule for control and experimental groups.

Figure 2. The average temperature of 3 fingers (thumb, middle finger, little finger) is plotted against time for one subject for one standard cold test. The right glove was removed at 15 minutes; the area of the curve from 15-135 minutes is the measure of cooling.

Figure 3. Oxygen consumption for control and experimental subjects during the 135 minute standard cold tests.

Figure 4. The change in the area of the temperature-time curve (units: C-minutes) from the Monday baseline values is illustrated for the 4 right hand sites for control and experimental subjects.

F-21

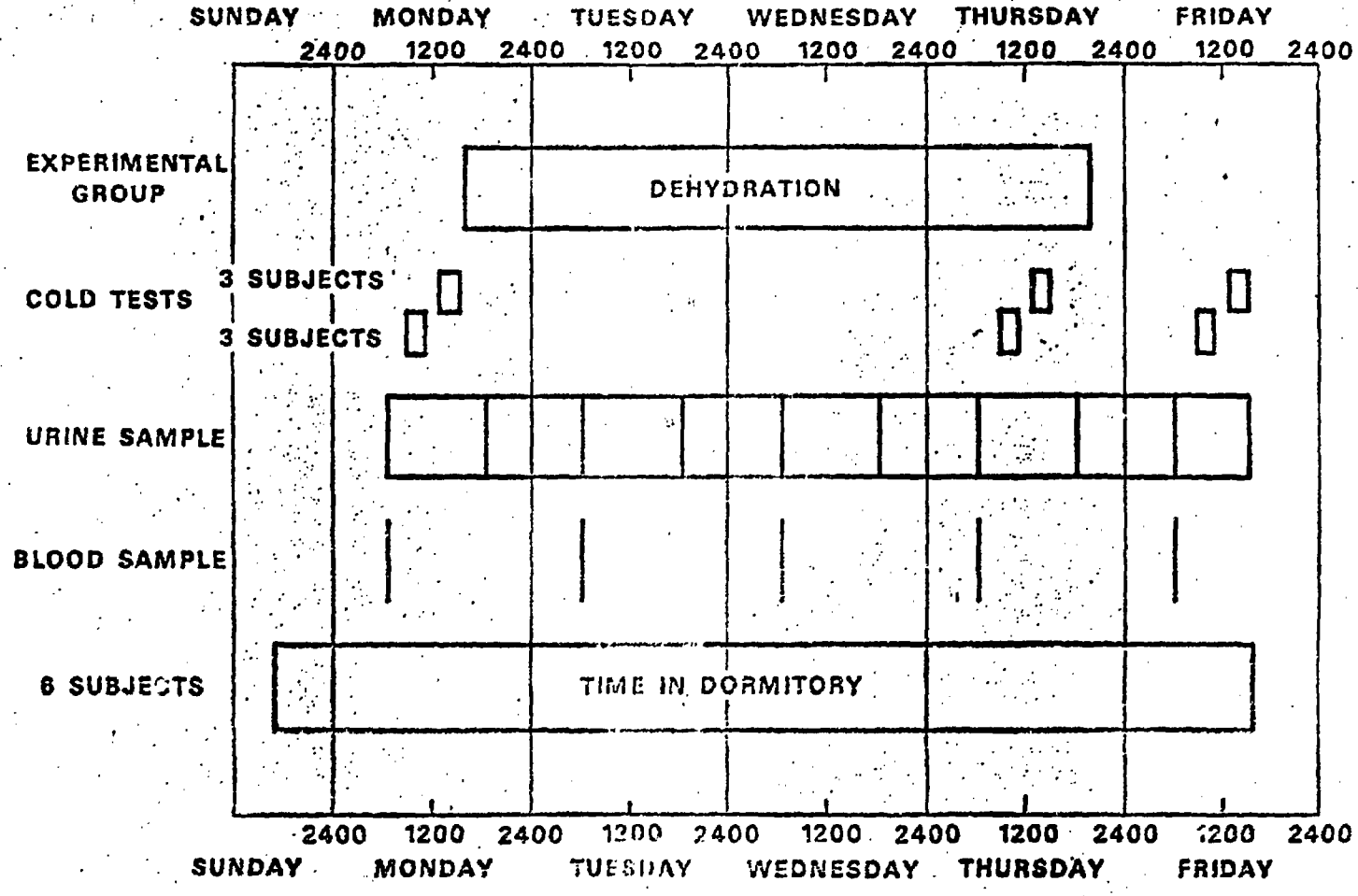
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
2400
1200
EXPERIMENTAL GROUP
DEHYDRATION
COLD TESTS
3 SUBJECTS
3 SUBJECTS
URINE SAMPLE
BLOOD SAMPLE
6 SUBJECTS
TIME IN DORMITORY

Fig 2

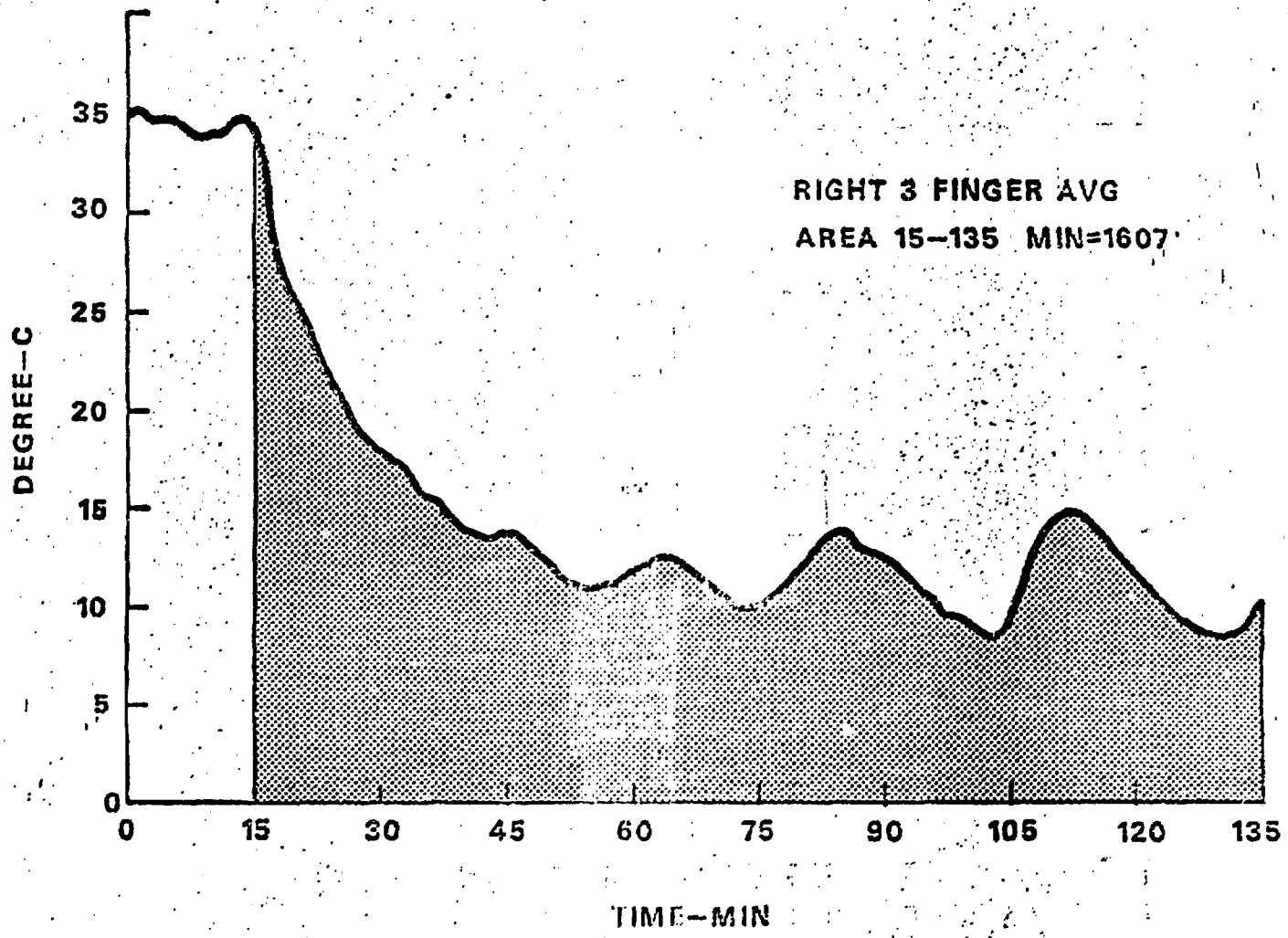
RIGHT 3 FINGER AVG
AREA 15–135 MIN=1607
DEGREE–C
35
30
25
20
15
10
5
0
0
15
30
45
60
75
90
105
120
135
TIME–MIN

Fig 3

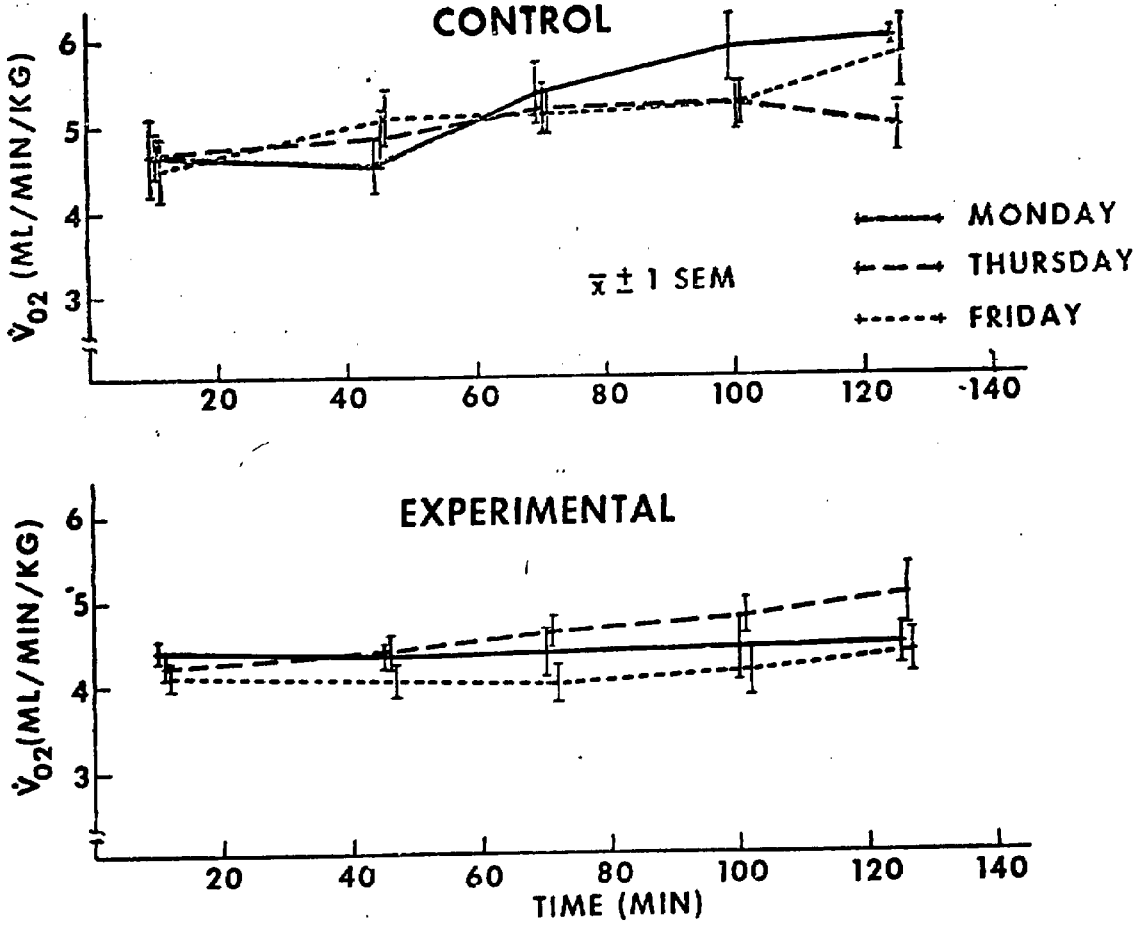
CONTROL
$\dot{V}_{O2}$ (ML/MIN/KG)
6
5
4
3
20
40
60
80
100
120
140
$\bar{x} \pm 1$ SEM
MONDAY
THURSDAY
FRIDAY
EXPERIMENTAL
$\dot{V}_{O2}$(ML/MIN/KG)
6
5
4
3
20
40
60
80
100
120
140
TIME (MIN)

Fig 4

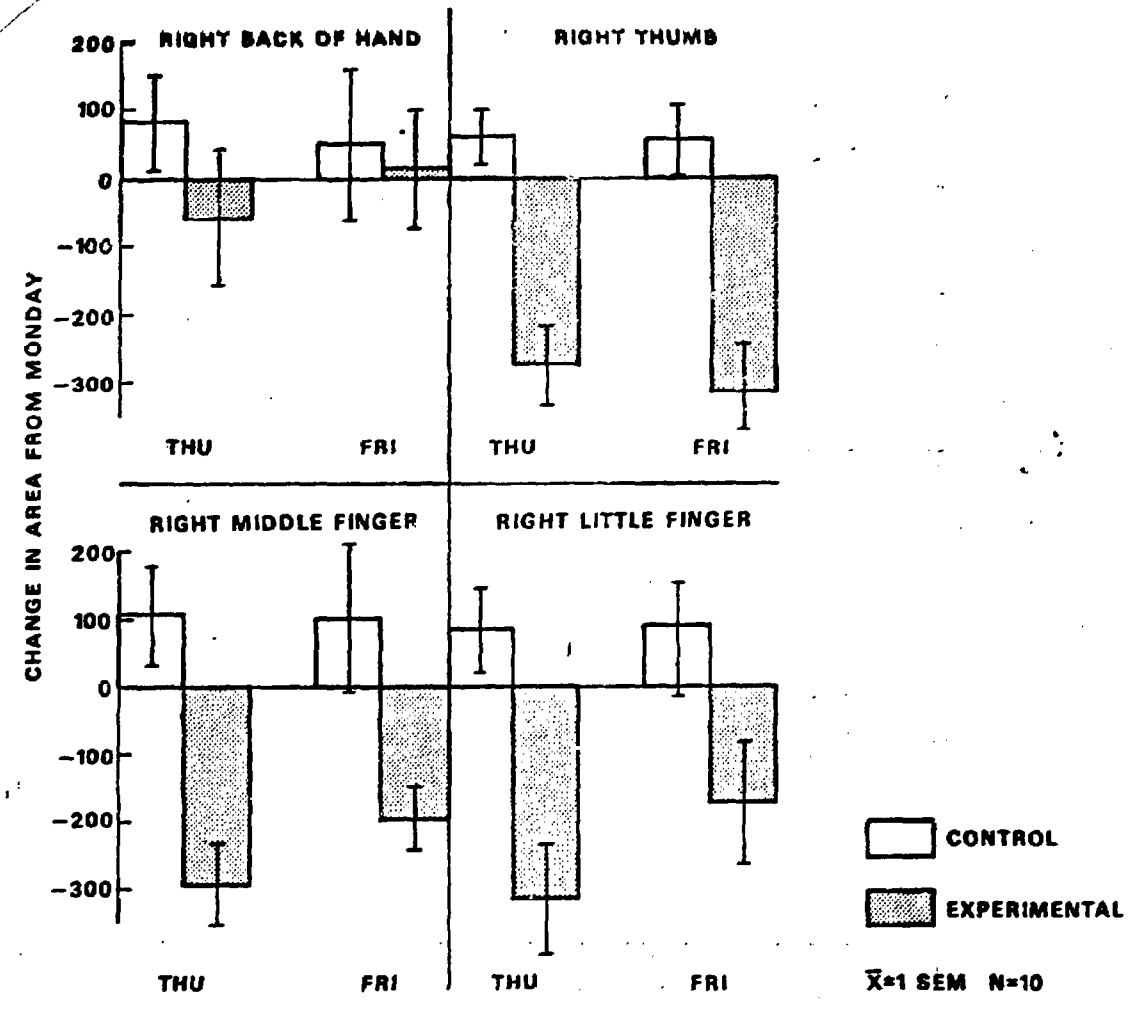
RIGHT BACK OF HAND
RIGHT THUMB
RIGHT MIDDLE FINGER
RIGHT LITTLE FINGER
CHANGE IN AREA FROM MONDAY
200
100
0
-100
-200
-300
THU
FRI
CONTROL
EXPERIMENTAL
X̄±1 SEM N=10

Table 1

CONTROL					EXPERIMENTAL				
	WT-KG	HT-IN	AGE	%BF		WT-KG	HT-IN	AGE	%BF
GH	73.3	71	21	14.6	MC	64.0	66	24	15.3
WK	83.7	70	24	28.2	RC	85.0	72	21	26.5
RK	75.2	69	21	18.6	RM	99.8	76	24	24.9
DR	67.3	70	20	17.1	WO	83.7	71	26	20.3
MS	68.0	69	21	17.8	BS	73.2	69	22	18.1
RP	75.2	70	20	20.8	RT	82.3	66	21	23.3
GD	77.9	69	21	23.3	PA	65.9	66	24	16.3
KF	62.3	69	20	14.4	AD	68.5	67	21	19.4
MH	72.8	70	22	17.8	JG	80.3	70	22	21.9
WH	69.2	67	21	18.7	JH	69.0	71	23	13.9
VL	64.9	67	20	19.2	JM	79.2	72	20	23.4
AM	89.2	72	21	27.7	TY	74.8	70	22	21.9
$\bar{X}$	73.3	69	21	19.9	$\bar{X}$	77.1	69.7	22.5	20.4
SEM	2.2	0.4	0.3	1.3	SEM	2.9	0.8	0.5	1.1

Table 2

BLOOD

VARIABLE	GROUP	MONDAY	THURSDAY	FRIDAY	$F_{1,14}$
HEMOGLOBIN	C	16.0±0.4	15.1±0.4	14.6±0.4	0.62
	E	15.5±0.2	15.5±0.1	14.8±0.2	
HEMATOCRIT	C	43.8±0.6	43.1±1.0	42.4±0.7	1.26
	E	44.5±0.6	43.3±0.5	42.2±0.4	
SODIUM	C	142.7±0.6	139.5±0.7	140.2±0.6	2.69
	E	139.8±1.6	144.3±2.6	139.4±1.3	
POTASSIUM	C	4.3±0.1	4.3±0.1	4.4±0.2	1.72
	E	4.8±0.2	4.4±0.2	4.3±0.2	
CHLORIDE	C	99.0±1.8	100.5±1.3	102.3±1.5	0.04
	E	99.0±1.8	102.9±1.6	100.2±1.9	
OSMOLALITY	C	288.2±0.5	294.3±3.3	292.1±2.3	18.40*
	E	290.3±1.7	302.7±1.2	294.7±1.1	

C = CONTROL E = EXPERIMENTAL *$P < 0.001$

$N_{CONTROL} = 6$ $N_{EXPERIMENTAL} = 10$ $\bar{X} \pm 1$ SEM

Table 3

URINE

VARIABLE	GROUP	M 0630 - M 1830	M 1830 - T 0630	Th 0630 - Th 1830	Th 1830 - F 0630	F 0630 - F 1530	$F_{1,17}$
VOLUME	C	813±86	582±89	750±127	521±49	465±59	53.31[a,*]
	E	760±59	382±28	178±19	373±38	303±40	
SPECIFIC GRAVITY	C	1.0225 ±0.0015	1.0227 ±0.0022	1.0178 ±0.0015	1.0210 ±0.0015	1.0195 ±0.0015	42.47*
	E	1.0238 ±0.0008	1.0273 ±0.0007	1.0308 ±0.0008	1.0314 ±0.0009	1.0268 ±0.0009	
SODIUM	C	161±16	144±16	150±19	119±17	146±13	0.14
	E	135±10	156±14	125±11	119±10	138±13	
POTASSIUM	C	49±5	35±4	52±7	34±4	71±9	20.05*
	E	48±3	57±6	80±7	52±4	57±4	
CHLORIDE	C	161±17	142±22	169±17	109±18	181±14	0.01
	E	145±17	159±11	151±10	96±13	146±13	
OSMOLALITY	C	787±56	807±94	689±77	759±67	729±53	22.38*
	E	867±42	1041±34	1010±53	1026±63	917±48	

C = CONTROL E = EXPERIMENTAL *$p < 0.001$ $\bar{X}$±1 SEM

$N_{CONTROL} = 10$ $N_{EXPERIMENTAL} = 9$ (except for Volume, N = 10) [a] $F_{1,18}$

table 4

AVERAGE MEAN WEIGHTED SKIN TEMPERATURE
135 MINUTE COLD TEST[a]

	MONDAY	THURSDAY	FRIDAY
CONTROL	31.50±0.51	31.92±0.43	32.28±0.25
EXPERIMENTAL	30.05±0.52	30.94±0.54	31.41±0.33

AVERAGE RECTAL TEMPERATURE
135 MINUTE COLD TEST[b]

	MONDAY	THURSDAY	FRIDAY
CONTROL	37.35±0.12	37.43±0.07	37.24±0.14
EXPERIMENTAL	37.22±0.05	37.49±0.13	37.32±0.09

$\bar{X}$±1 SEM, N = 10 $^{a}F_{1,18} = 0.02$ $^{b}F_{1,18} = 0.00$

Table 5

AREA UNDER CURVE
RIGHT 3 FINGER AVERAGE

	N	PRETEST	MONDAY	THURSDAY	FRIDAY
CONTROL	5	1413±179	1334±221	1386±202	1388±192
CONTROL	10		1308±112	1393±104	1390±122
EXPERIMENTAL	10	1659±125	1646±128	1351±100	1418± 78

$\bar{X}$±1 SEM